

Three-Dimensional Analysis of Crack in Centrally Perforated Photoelastic Cylinders under Internal Pressure



C. T. Liu

AFRL/PRSM

Edwards AFB CA 93524-7680, USA

C. W. Smith

ESM Dept.

**Virginia Polytechnic Institute & State
University**

Blacksburg, VA 24061, USA

Distribution A: Approved for public release; distribution unlimited

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE JUL 2004		2. REPORT TYPE		3. DATES COVERED -	
4. TITLE AND SUBTITLE Three-Dimensional Analysis of Crack in Centrally Perforated Photoelastic Cylinder under Internal Pressure				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER 2302	
6. AUTHOR(S) C Liu; C Smith				5d. PROJECT NUMBER 0378	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Air Force Research Laboratory (AFMC), AFRL/PRSM, 10 E. Saturn Blvd., Edwards AFB, CA, 93524-7680				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT The objectives of this study were to (1) Investigate the Effect of Crack Geometry and Location on the Crack Growth Behavior in Centrally Perforated Cylinders under Internal Pressure. (2) Determine the Safety Factor for a Two-Dimensional Analysis of a Deep Part-Through crack.					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES 16	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			



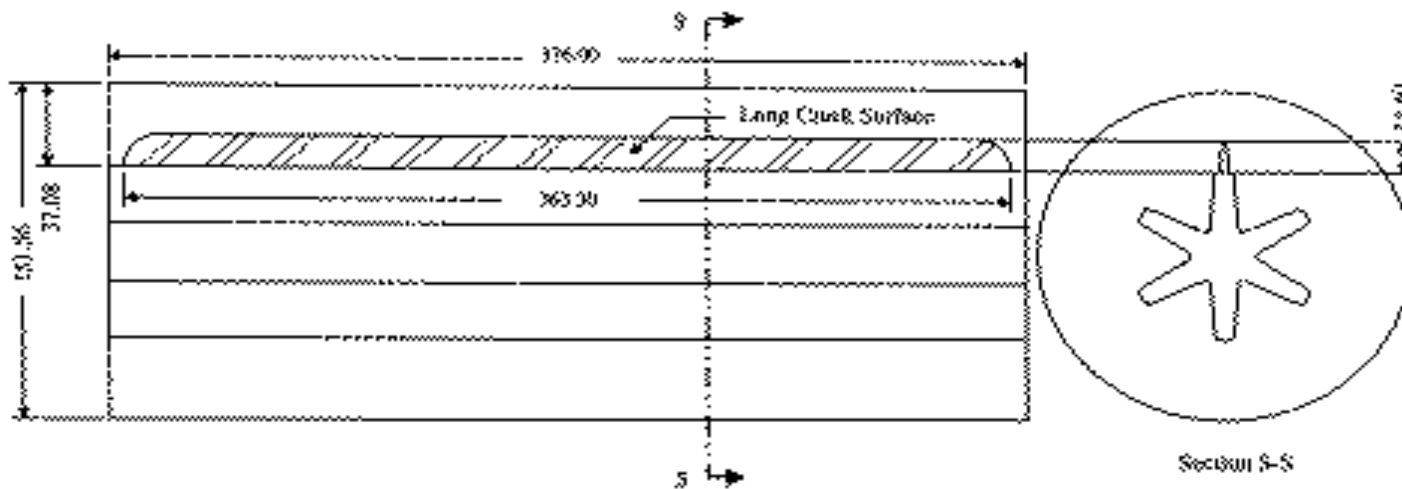
Objectives



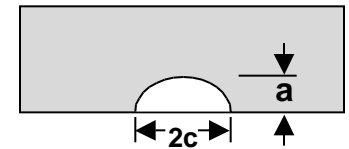
- **Investigate the Effect of Crack Geometry and Location on the Crack Growth Behavior in Centrally Perforated Cylinders under Internal Pressure.**
- **Determine the Safety Factor for a Two-Dimensional Analysis of a Deep Part-Through crack.**



Specimen Geometries



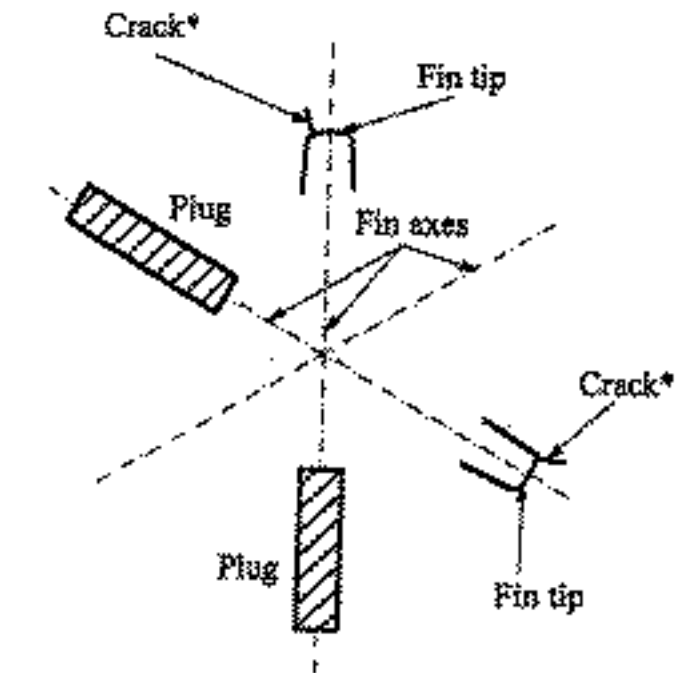
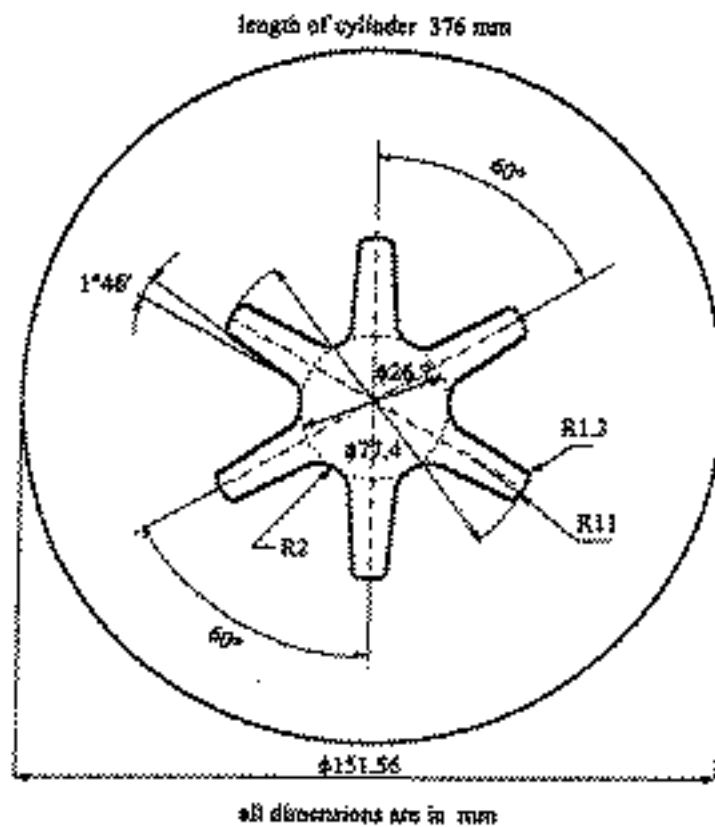
All dimensions in mm



Part-Through Crack



Specimen Dimensions and Crack Locations

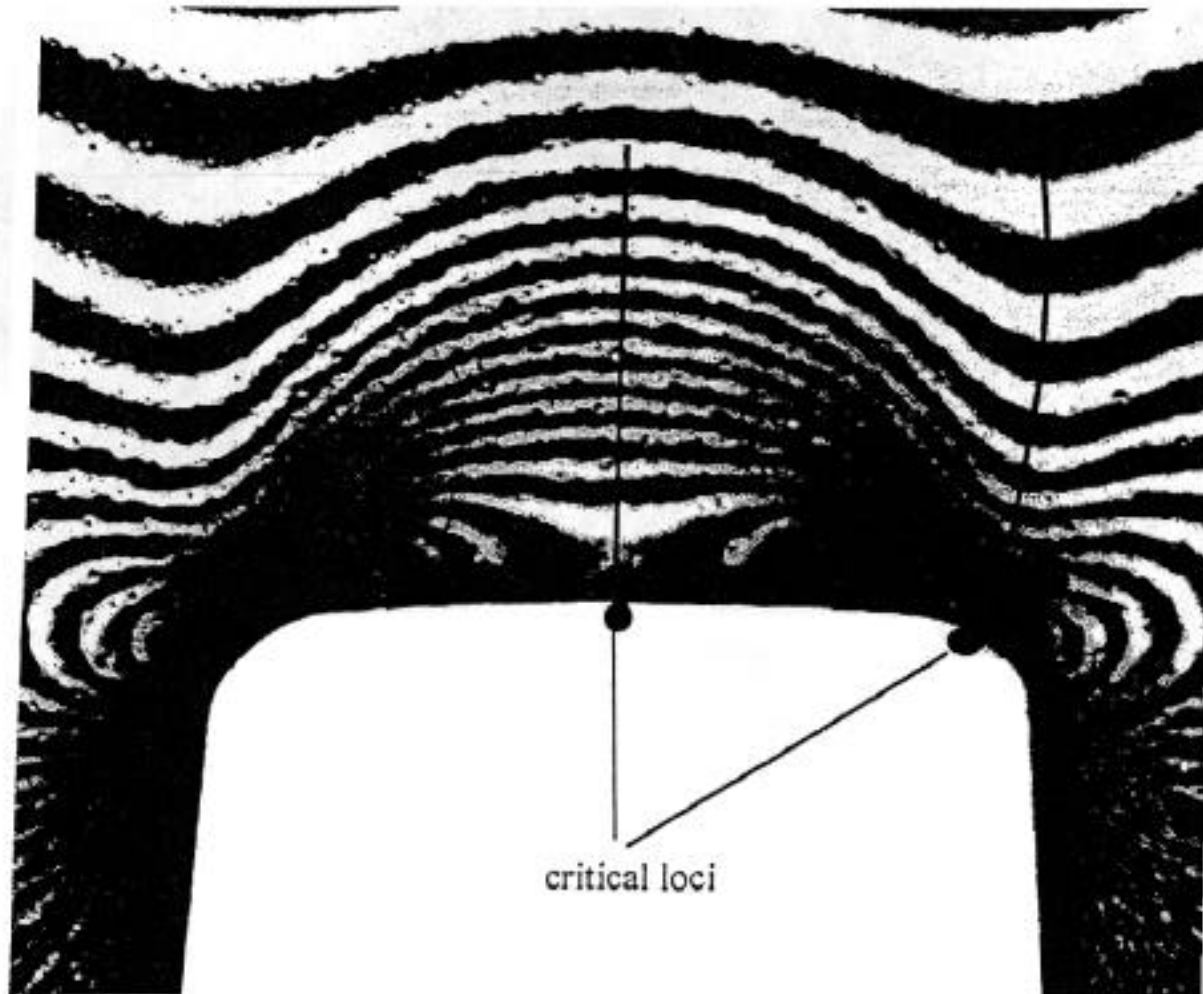


* Path of crack to maximum depth



16Jun04 LIU.ppt

Fringe Patterns Near Critical Loci at Fin Tip

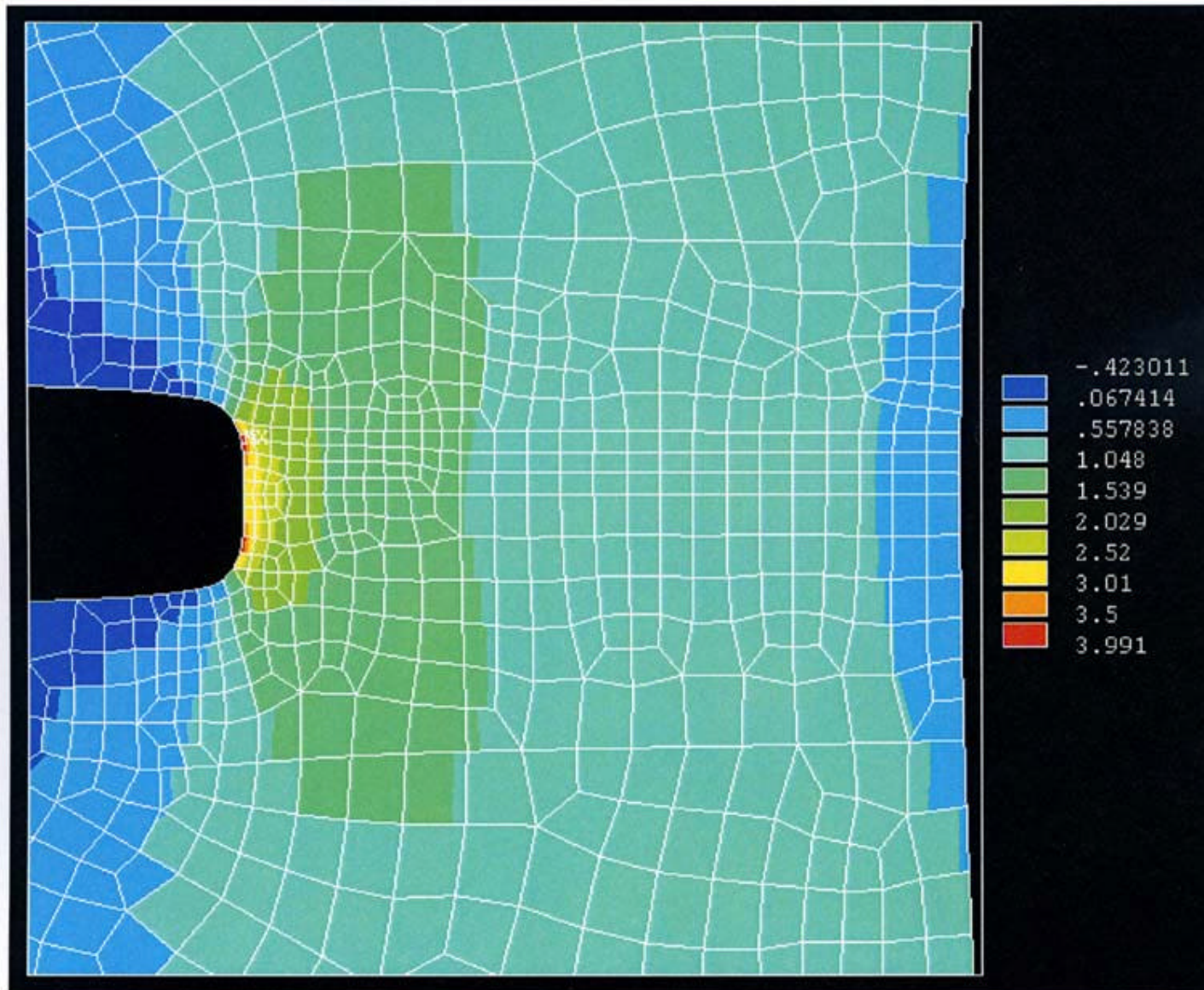


Distribution A: Approved for public release; distribution unlimited



16Jun04 LIU.ppt

Contour Plot of Stress σ_{yy} (No Crack)

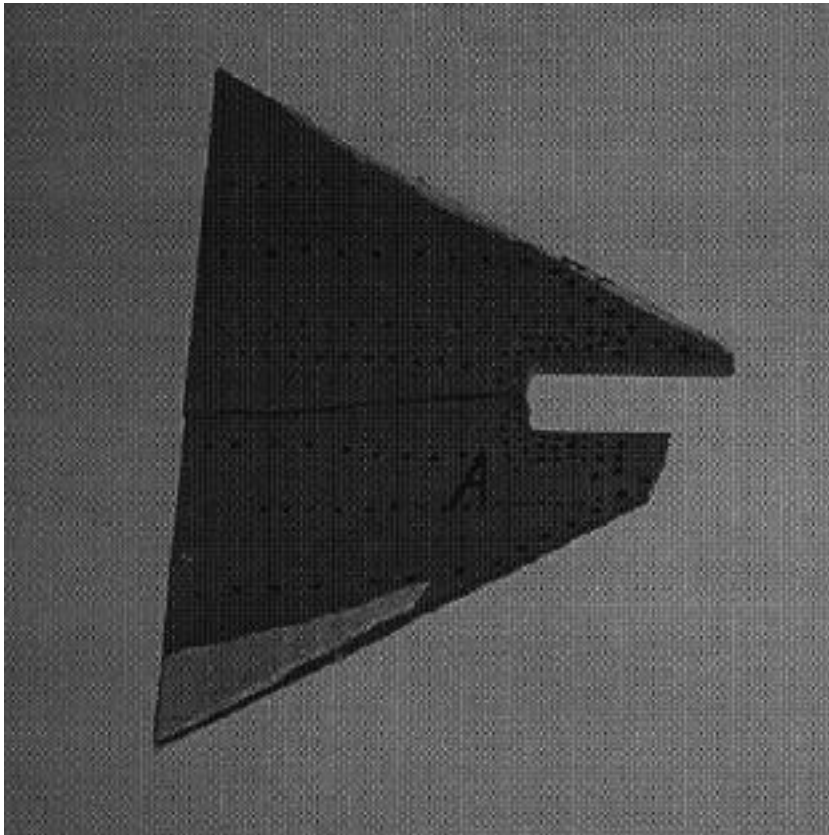


Distribution A: Approved for public release; distribution unlimited

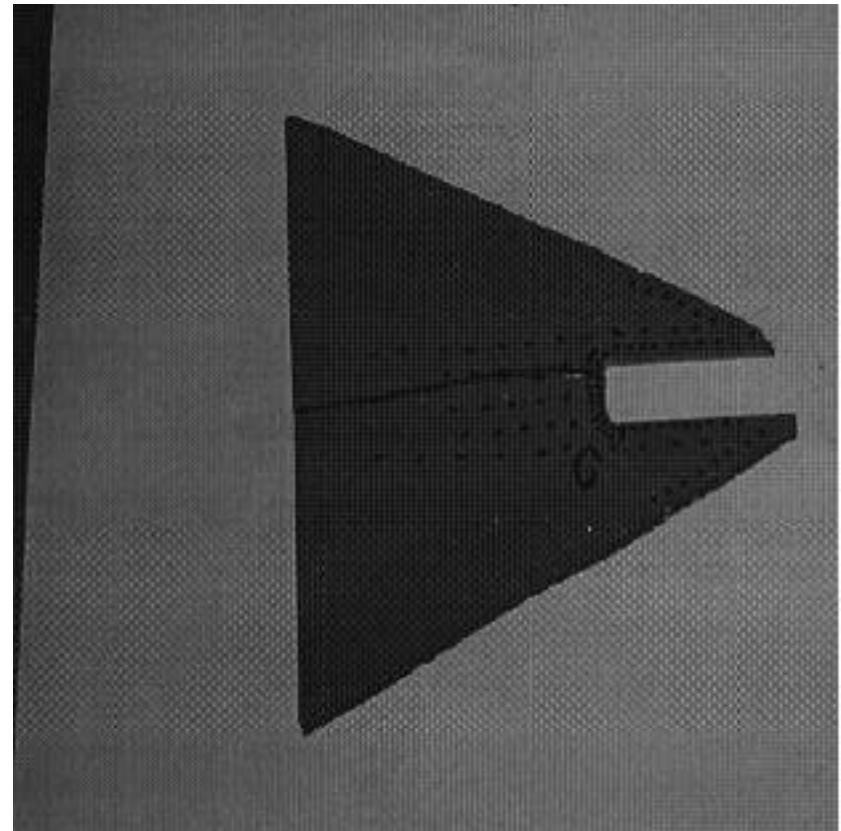


16Jun04 LIU.ppt

Two-Dimensional Crack Growth Tests



A



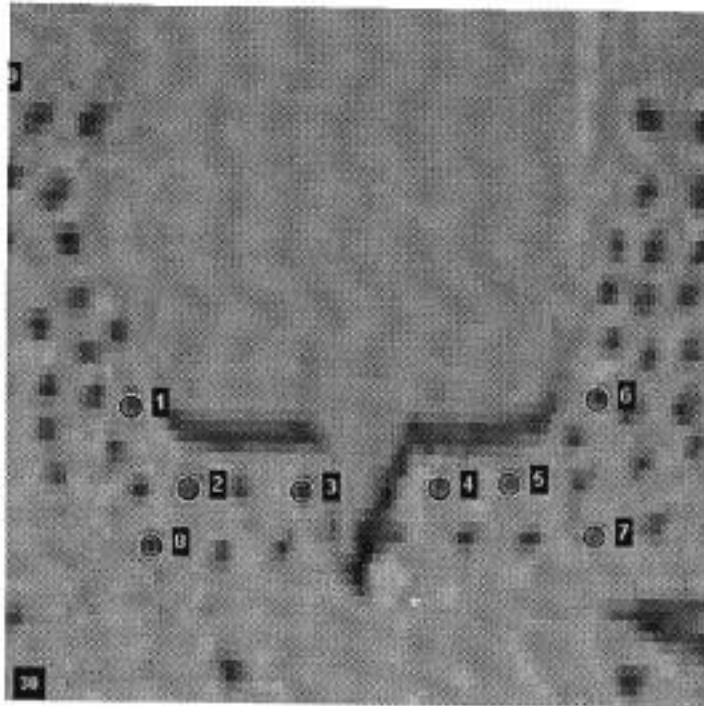
B

Distribution A: Approved for public release; distribution unlimited



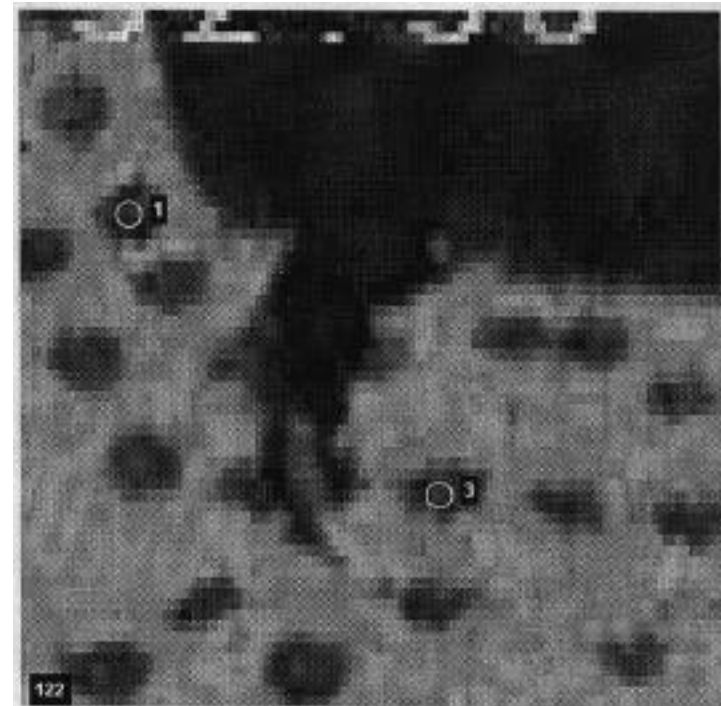
16Jun04 LIU.ppt

Two-Dimensional Crack Growth Tests



A

Crack initiated at the center of the fin

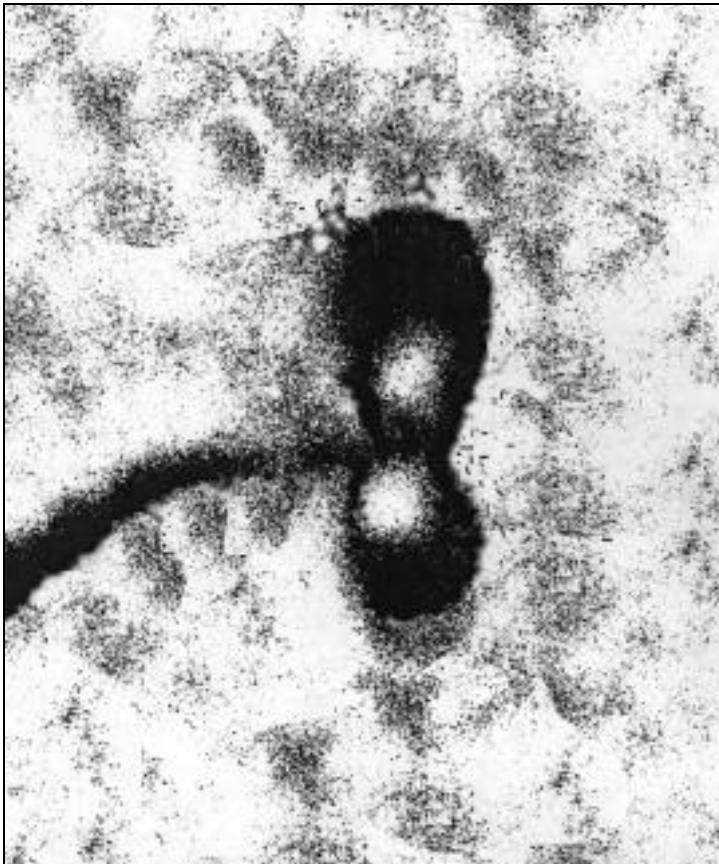


B

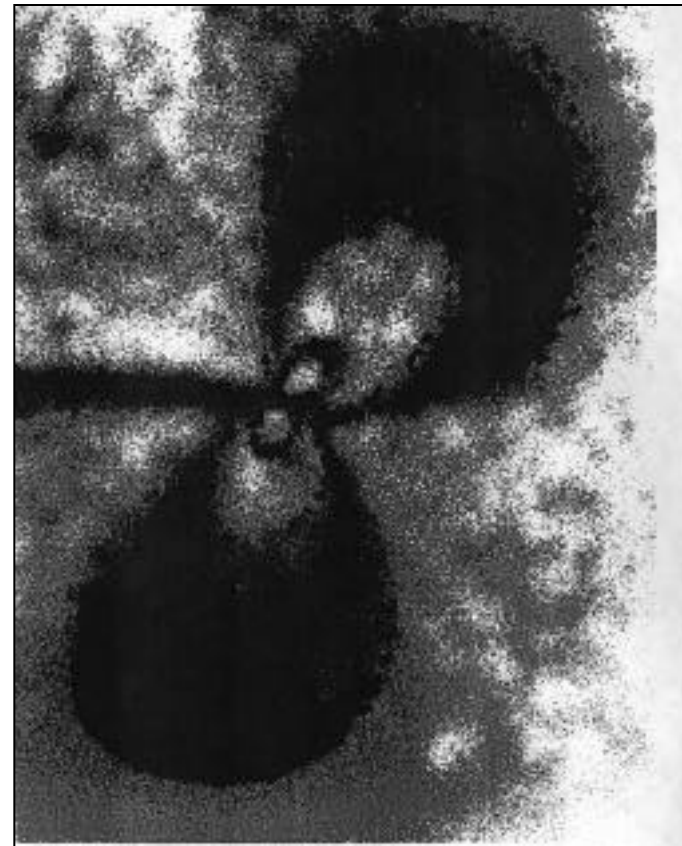
Crack initiated at the corner of the fin



Photoelastic Fringe Patterns



**Crack Turning
Completed**

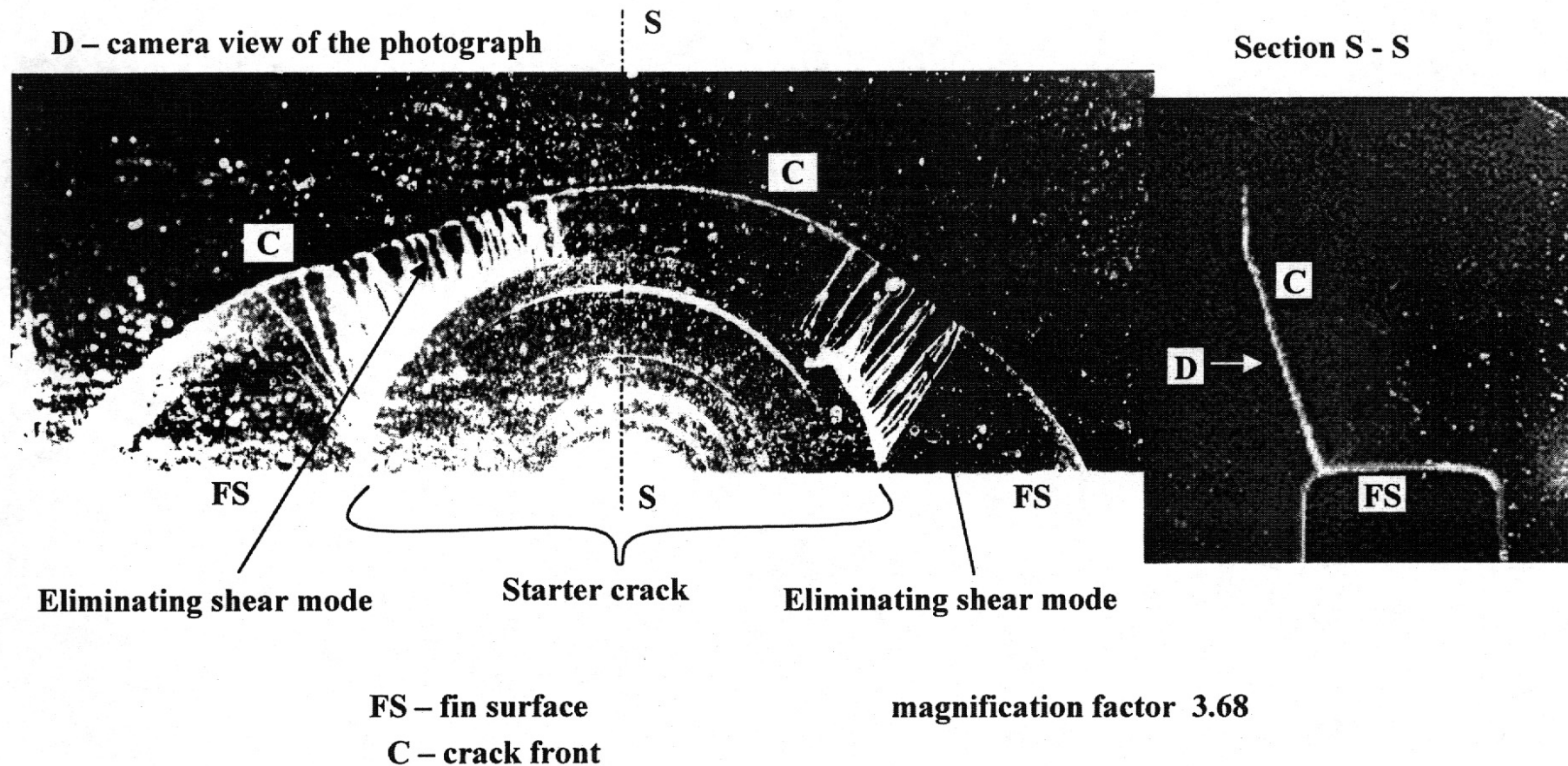


**Crack Turning
Incomplete**



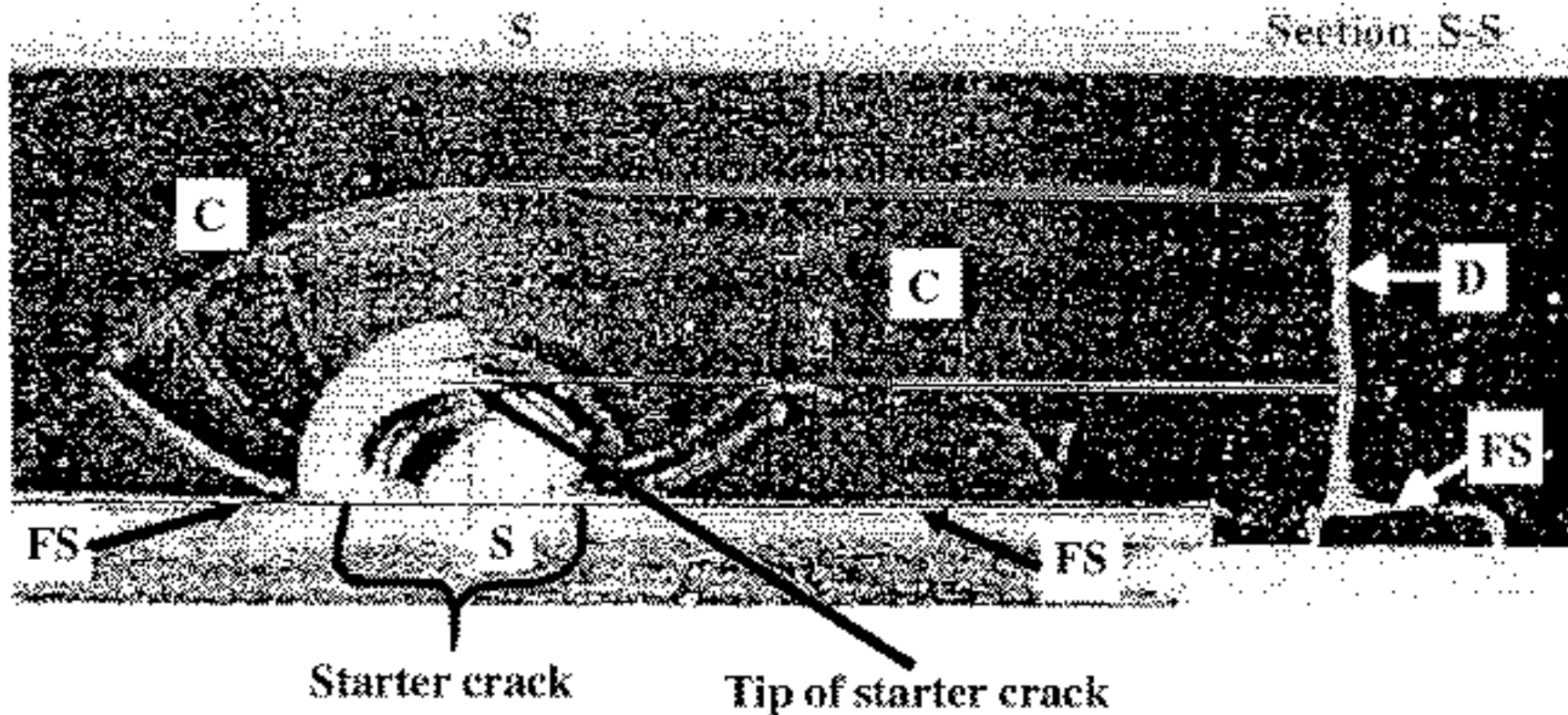
16Jun04 LIU.ppt

Typical Off-Axis Inclined Crack Which is Perpendicular to the Fin Surface





Typical Off-Axis Straight Crack Which is Parallel to the Fin Axis



Fin surface

C - crack front

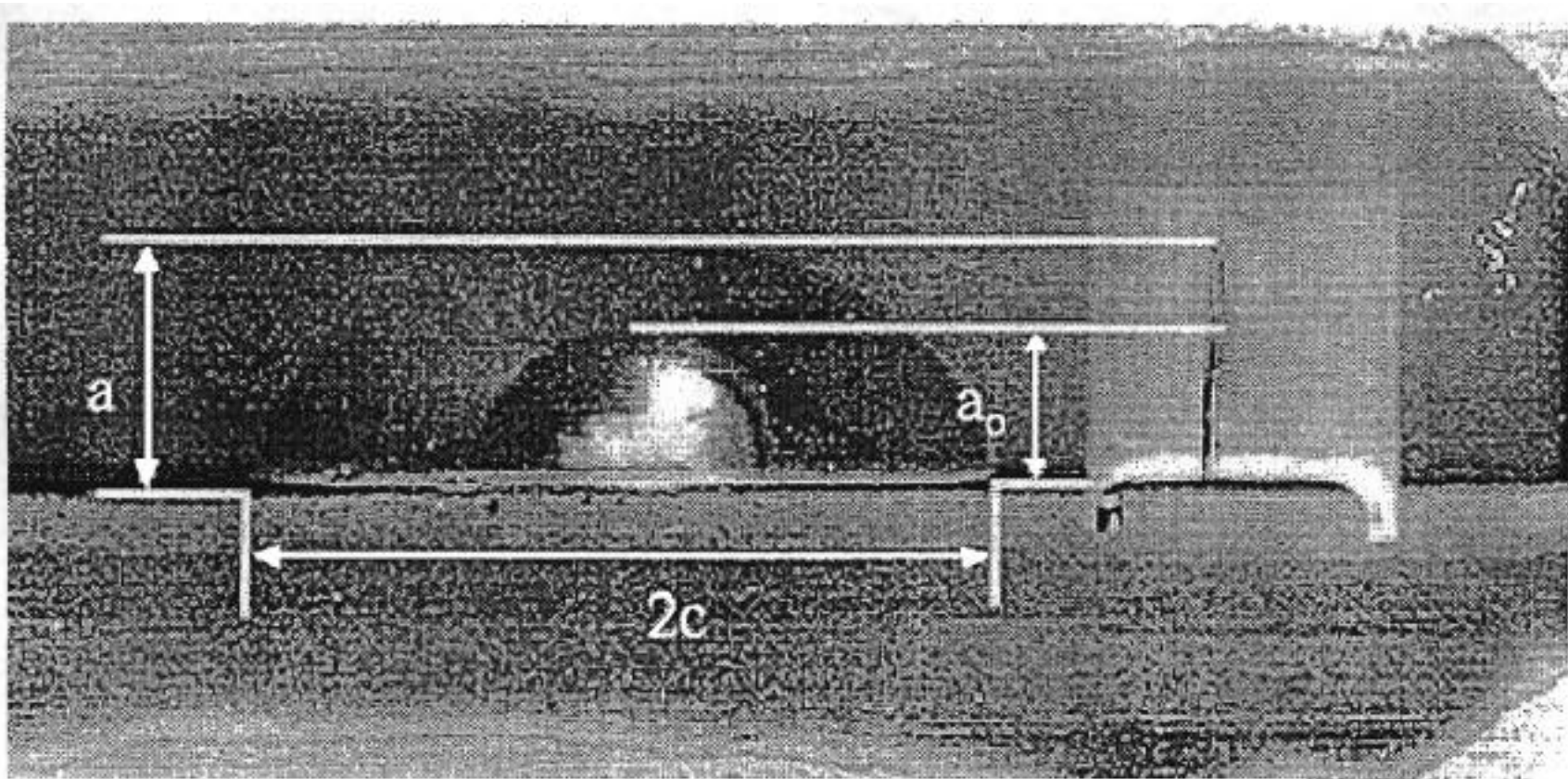
D - camera view of the photograph

Magnification factor: 1.73



16Jun04 LIU.ppt

Typical Symmetric Crack Which is Near the Fin Axis

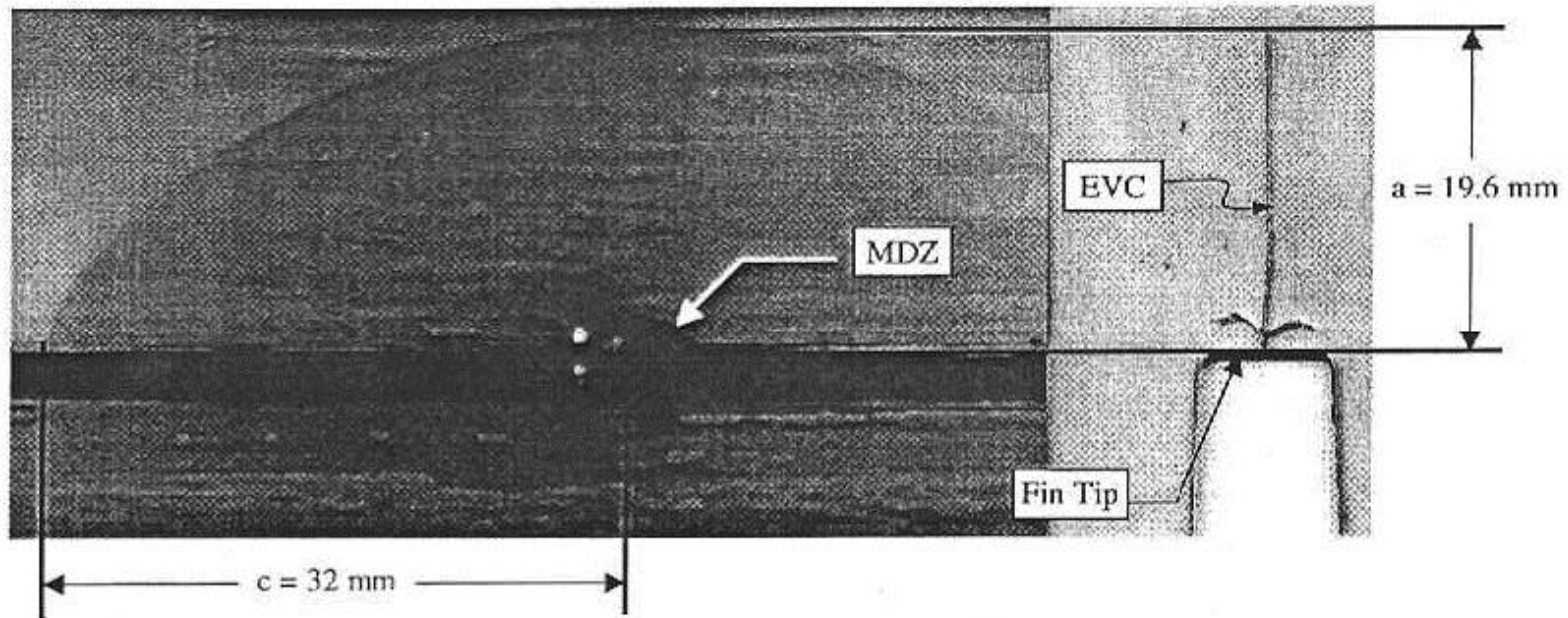


a_0 - initial crack
 a - final crack

M.F 2.52



Top and Edge Views of Crack



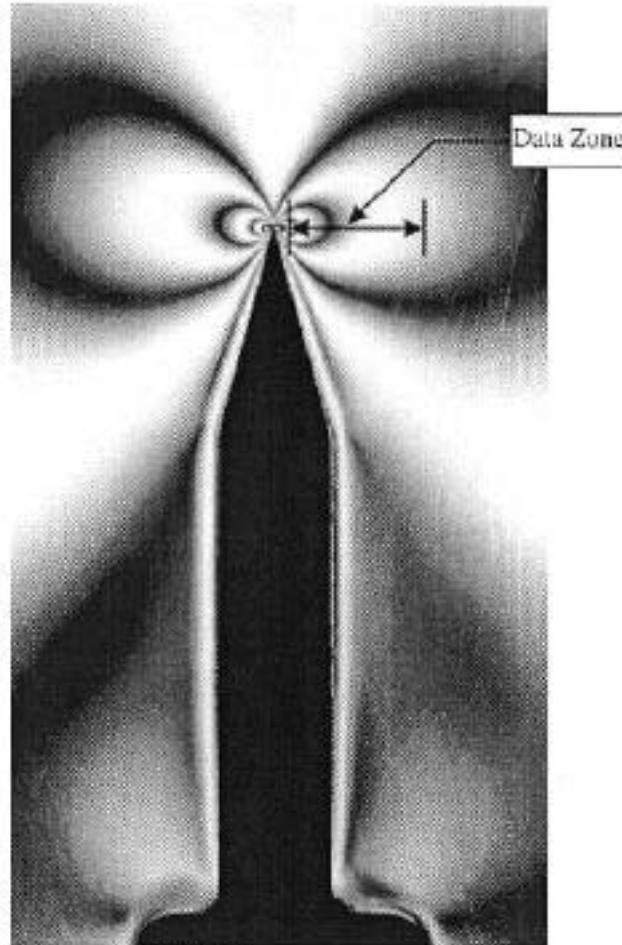
MDZ – Material Damage Zone
EVC – Edge View of Crack



Fringe Patterns near the Tip of a Symmetric Crack



Center Slice ($t = 4.29$ mm)



P_{eff} 2.3×10^{-2} MPa
 c_p 175.30 mm
 a_p 19.6 mm
 Data zone: $(r_{ave})_2 - (r_{ave})_1 = 4.2635 - 0.4564 = 3.807$ mm



Summary of Mode I Stress Intensity Factor K and Normalized Mode I Stress Intensity Factor F



	a	c	a/c	a/t	Psf	K	F
Test 3A	15.38	30.74	0.50	0.41	.033	0.31	1.67
Test 5B	14.60	181.65	0.04	0.41	.041	0.74	2.49



Conclusions



- When the crack is perpendicular to the free surface, a significant three-dimensional effect occurs during crack turning.
- When the crack is either parallel to or in the fin axis, there is no crack turning observed and the crack grows under normal mode only.
- During crack turning crack grows under normal and shear modes.
- For a same a/t ratio the Mode I stress intensity factor for the long crack is much higher than that of the part-through crack.
- The two-dimensional analysis of the deep part-through crack yields a safety factor of 1.49.
- The practice of using two-dimensional analysis to determine the criticality of a deep part-through crack is conservative.